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On the Evidence of a past Connection between four widely separated Southern Stars. By E. J. Stone, M.A., F.R.S.

I have found it desirable, in the formation of my Cape Catalogue, to examine the cases in which large proper motions have been assigned to Southern Stars in the British Association Catalogue. In the greater number of cases these large proper motions have not been confirmed; but in the following group of stars the proper motions are large and fairly well determined. These proper motions appear to me otherwise interesting, and to indicate the existence, in the past, of some close connection between stars which are now widely separated.

The following data are extracted from the Cape Catalogue now passing through the press:—

1880.

Name.	Mag.	R.A. h m s	Precess. s	P.M. s	N.P.D. ° ′ ″	Precess. ″	P.M. ″
ζ Toucani	4·	0 13 48·60	+2·8953	+0·280	155 34 49·03	−20·018	−1·13
e Eridani	4·5	3 15 8·16	+2·1169	+0·266	133 31 46·81	−13·214	−0·75
ζ^1 Reticuli	5·6	3 15 9·95	+1·0954	+0·194	153 2 5·58	−13·212	−0·65
ζ^2 Reticuli	5·6	3 15 36·39	+1·0980	+0·190	152 57 53·21	−13·184	−0·65

The angular proper motions of these stars are 2″·13, 2″·99, 1″·47, and 1″·45 respectively. It will be remarked that the proper motions are exceptionally large in both elements, and that they have the same signs for all the stars. In my opinion these facts are not sufficient to prove that the stars have belonged to a stellar system, but they undoubtedly raise a strong presumption that such may have been the case.

We have observations of these stars extending over a period of nearly 130 years. To avoid the complications introduced by changes in the axes of reference, I shall refer the motion of each star to the other stars, and discuss the changes of angular distance.

1st.—For the distances of the close pair of stars ζ^1 and ζ^2 *Reticuli* we have

Epoch.	Distance. ° ′ ″	
1750	0 5 5	Lacaille.
1825	0 5 8·08	Brisbane.
1840	0 5 9·27	Maclear.
1880	0 5 8·40	Stone.

From which we deduce for the epoch 1880 + *t*

Distance = 0° 5′ 9″·39 + 0″·03 × *t*, when Lacaille's observations are used.

Distance = 0 5 8·79 + 0·0059 × *t*, when Lacaille's observations are excluded.

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Whilst the proper motions of these stars, therefore, have carried each of them through an angular space of 189″, the angular distance of the stars has changed but very little indeed. The slight change which has taken place shows that the angular separation of these stars was formerly less than at the present time. There are only one or two stellar parallaxes at present known as large as 0″·5; but with such a parallax as this these stars must, in the last 130 years, have been carried progressively through at least 34,700,000,000 miles without any corresponding separation of their centres.

2nd.—For the distances between the star *e Eridani* and the mean position of the two stars ζ^1, ζ^2 *Reticuli*, we have

Epoch.	Distance. °	′	″
1750	19	28	2·55
1825	19	28	8·00
1840	19	28	8·70
1880	19	28	12·65

From these we deduce for the epoch $1880+t$

Distance = 19° 28′ 12″·29 + 0″·0762 × t, including Lacaille.
Distance = 19° 28′ 12″·57 + 0″·0877 × t, excluding Lacaille.

The rate of separation between the star *e Eridani* and the centre of gravity of ζ^1 and ζ^2 *Reticuli* is very small compared with the proper motions of the stars themselves, but the distance is increasing.

The star *e Eridani* therefore participates in the large proper motion of ζ^1 and ζ^2 *Reticuli*, but is very slowly separating from that system.

3rd. For the distance between ζ *Toucani* and ζ^1 and ζ^2 *Reticuli* we have

Epoch.	Distance. °	′	″
1750	19	25	16
1825	(19	25	6)
1840	19	25	15
1880	19	25	18

The distance deduced from Brisbane's observations is discordant. The right ascensions of Brisbane's Catalogue are exceedingly rough, and the distance is here greatly affected by errors in right ascension. The general result, however, is the same whether Brisbane's observations be included or excluded. Rejecting Brisbane's distance, we have for the epoch $1880+t$

Distance = 19° 25′ 17″ + 0″·006 × t, including Lacaille's observations.
Distance = 19° 25′ 18″ + 0″·075 × t, from the Cape observations alone.

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The distance is increasing, but very slowly. The distance is nearly the same as in case (2) and the velocity of separation is the same if determined from the Cape observations which are alone corrected for proper motions to the epochs.

In this case also we have the stars participating in a large common proper motion, but slowly separating from each other.

4. The following are the distances between the stars ζ *Toucani* and *e Eridani*:—

Epoch.	Distance. ° ′ ″	Obs.—Comp. ″
1750	33 4 31	+0·9
1825	33 4 56·5	−0·6
1840	33 5 2·0	−0·5
1880	33 5 16·9	0·0

From which we obtain for the epoch 1880 + t

$$\text{Distance} = 33^\circ\ 5'\ 16''\!\cdot\!9 + 0''\!\cdot\!36 \times t.$$

The distance is increasing as in the other cases considered. The rate of change is larger than in the other cases, but it is still much smaller than the common proper motion of the group, and the distance itself is much greater than in the cases (1), (2), and (3.)

It appears therefore—

α. The four stars of the group under consideration have proper motions much larger than the average proper motions of stars.

β. That the stars have a common proper motion of more than a second of arc.

γ. That each star of the group is moving away from every other star of the group by quantities which are small compared with the common proper motion of the group.

δ. That, roughly speaking, the velocities of separation are larger, the larger the present angular separation of the stars.

The two stars ζ^1 and ζ^2 *Reticuli* have been shown to be separating very slowly indeed, and it has then been shown that the triangle formed by joining ζ *Toucani*, *e Eridani*, and the mean position of ζ^1 and ζ^2 *Reticuli* is slowly expanding. It is clear, therefore, that in the remote past the stars of the group must have been much closer together than at present. By a stellar system I mean a group of stars in which the several stars are bound together by much closer gravitational bonds than those which connect the members of one system with the members of another system. Have the stars in the group under consideration ever formed such a stellar system? It appears to me at least exceedingly probable that such must have been the case; but I fear the solution of the problem cannot be carried much further than I have already done.

If we suppose two stars to pass through a point and to

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separate by moving uniformly along two straight lines, then the distance d can be expressed as follows:—

$$\tan d = \frac{a + bt^2}{1 + \alpha t + \beta t^2}.$$

We have no knowledge of the time t at which the angular separation of stars is supposed to be small, and the formula therefore contains five unknown quantities. But our observations, which only extend over 130 years, are fairly represented by a formula only containing the first power of t. We are therefore only really given the distance d and its rate of change for the present epoch. If the stars have ever been sufficiently close to form a stellar system, our accurate astronomy is too much a thing of yesterday to furnish data for the determination of the time at which this must have taken place. The points to which I have called attention appear, however, to point clearly in the direction indicated; but, with respect to time, all we can safely say is that the stars cannot have been sufficiently near to sensibly affect each other's motions within the last 300,000 years.

5. I shall next give the distances, for the epoch $1880+t$, between the star *β Hydri* and the group of stars considered above.

The following data are extracted from my Cape Catalogue:—

1880.

Name.	Mag.	R.A.	Precess.	P.M.	N.P.D.	Precess.	P.M.
		h m s		s	° ′ ″		″
β Hydri	3	0 19 25·32		+0·720	167 55 48·68		−0·32

The distances between *β Hydri* and

	° ′ ″	″
ζ Reticuli =	20 1 12	−0·33 × t;
ζ Toucani =	12 21 24·63	+0·892 × t;
e Eridani =	38 29 33	−0·44 × t.

The star *β Hydri* has therefore a large velocity of separation from *ζ Toucani*, and is moving towards *ζ Reticuli* and *e Eridani*. *β Hydri* cannot therefore have been a member of the same stellar system as *ζ Reticuli*, *ζ Toucani*, and *e Eridani*.

It will be remarked, however, that *β Hydri* has large proper motions in right ascension and north polar distance of the same signs as those of the stars contained in the group under consideration, and that these conditions are therefore not alone sufficient to prove that stars whose proper motions satisfy them belong to a system.

I have examined several other cases, but I have not met with any other stars belonging to the same stellar system.

If we assume the masses of these fourth and fifth magnitude stars to be equal to that of our Sun, and the annual parallaxes $=0''{\cdot}5$, the equation of *vis viva* will show that no changes of

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proper motion affecting the tenths will have taken place since the angular separation of the stars amounted to a couple of minutes. It appears to me that such a system as that under consideration in the present paper may have originated from a star, or a system of two stars like α^1 and α^2 *Centauri*, with a large proper motion being brought, by reason of that large proper motion, sufficiently near another system to disturb the relative motions of each, and that both systems have thus been changed from close into open orbits. I consider that we now see each star moving with the common motion of the centre of gravity combined with the velocity due to its motion about the centre of gravity of the whole system, which latter velocity has for a long period past been sensibly an uniform velocity in a straight line. It would be interesting to examine the annual parallaxes of these stars.

1879, *October* 25.

Conjunction of Mars and Saturn, June 30, 1879, *observed at the Observatory, Melbourne.* By R. L. J. Ellery.

Observations with South Equatoreal, 8″ Aperture, and Parallel Wire Micrometer. Power 250.

Melbourne Mean Time.				Distance by Micrometer.	Distance, corrected, of Semi-diam.	Position of *Mars*.	
	h	m	s	″	″	°	′
June 30	16	25	33	113·19	110·50	294	37
		48	3	99·85	97·25	312	24
		58	19	94·99	92·39	322	24
	17	2	22	93·18	90·58	327	42
		6	37	91·28	88·68	331	12
		12	32	91·66	89·06	336	4
		14	12	90·52	87·92	338	7
		16	20	90·13	87·53	...	
		19	40	90·33	87·73	...	
		22	29	90·71	88·11	347	52
		24	41	91·47	88·87	...	
		27	0	91·47	88·87	...	
		28	25	92·23	87·63	354	2
		32	19	94·14	91·54	...	
		33	38	94·71	92·11	357	42
		35	35	95·85	93·25	359	22
		38	42	97·38	94·78	...	
		43	11	102·52	99·92	4	22

Remarks.—The measures having been made from south limb of *Mars* to south limb of *Saturn*, and the first column of distances corrected for wire zero only, a correction of $-2''\cdot60$ for diff. of semi-diameter is applied, which gives the distances in second column. No correction for parallax or refraction has been applied.